Membranes for Hydrocarbon Recovery in Petrochemical, Refinery and Natural Gas Processing Applications

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MTR

Membrane Technology and Research, Inc.

- Company founded in 1982, dedicated to development and commercialization of membrane-based separation technologies.
- Novel technologies based on innovative R&D, funded largely through U.S. government contracts (Department of Energy, Environmental Protection Agency, National Science Foundation, Office of Naval Research, Department of Agriculture).
- Most commercial applications to date involve separations in the gas phase.
- Several liquid phase separation applications are under development

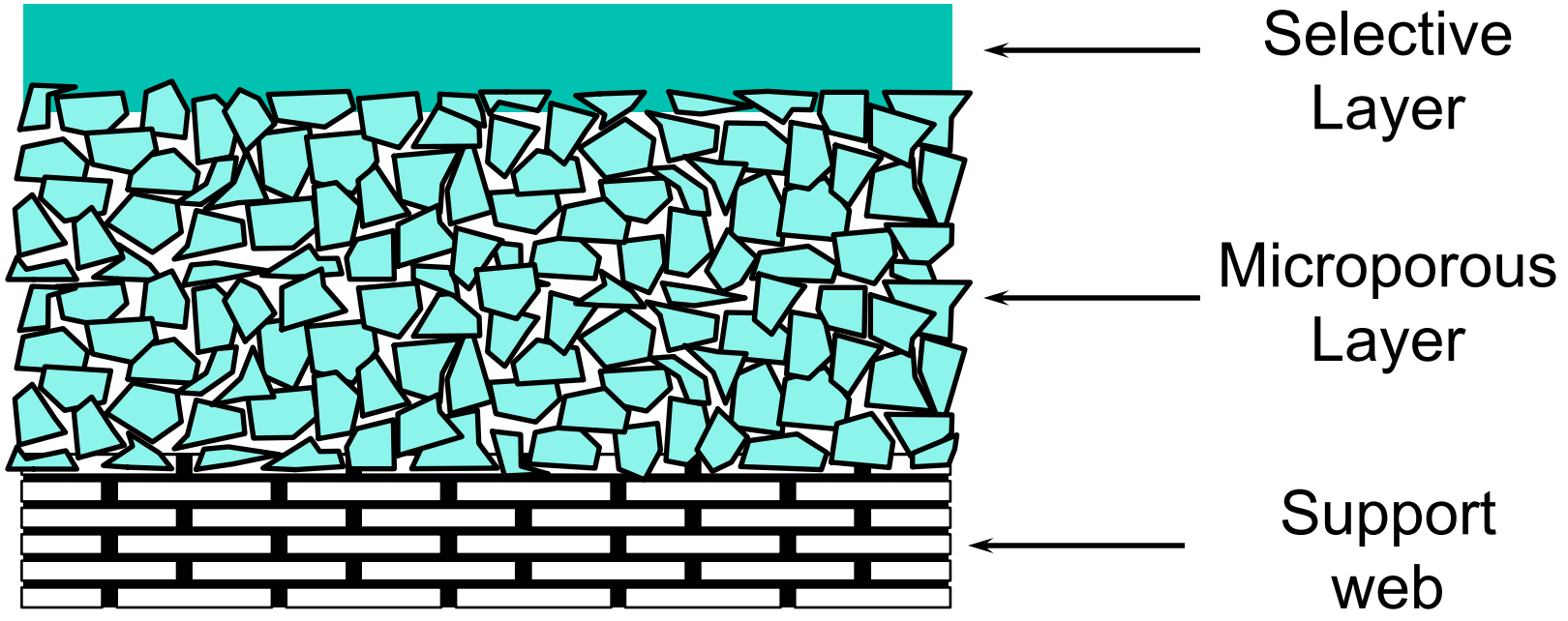
COMPANY STRUCTURE

- Marketing and Sales
  - Houston and Brussels Sales Offices
- Engineering
- Membrane and Module Manufacturing
- Research and Development
- Finance and Administration

Approximately 40 employees total.

Large installations are constructed by third party fabricators based on MTR engineering packages.

MTR Multilayer Composite Membrane



MEMBRANE PERMEATION BEHAVIOR

Permeation through nonporous polymer film is governed by diffusion and sorption.

Diffusion favors smaller molecules.
Sorption favors larger molecules.

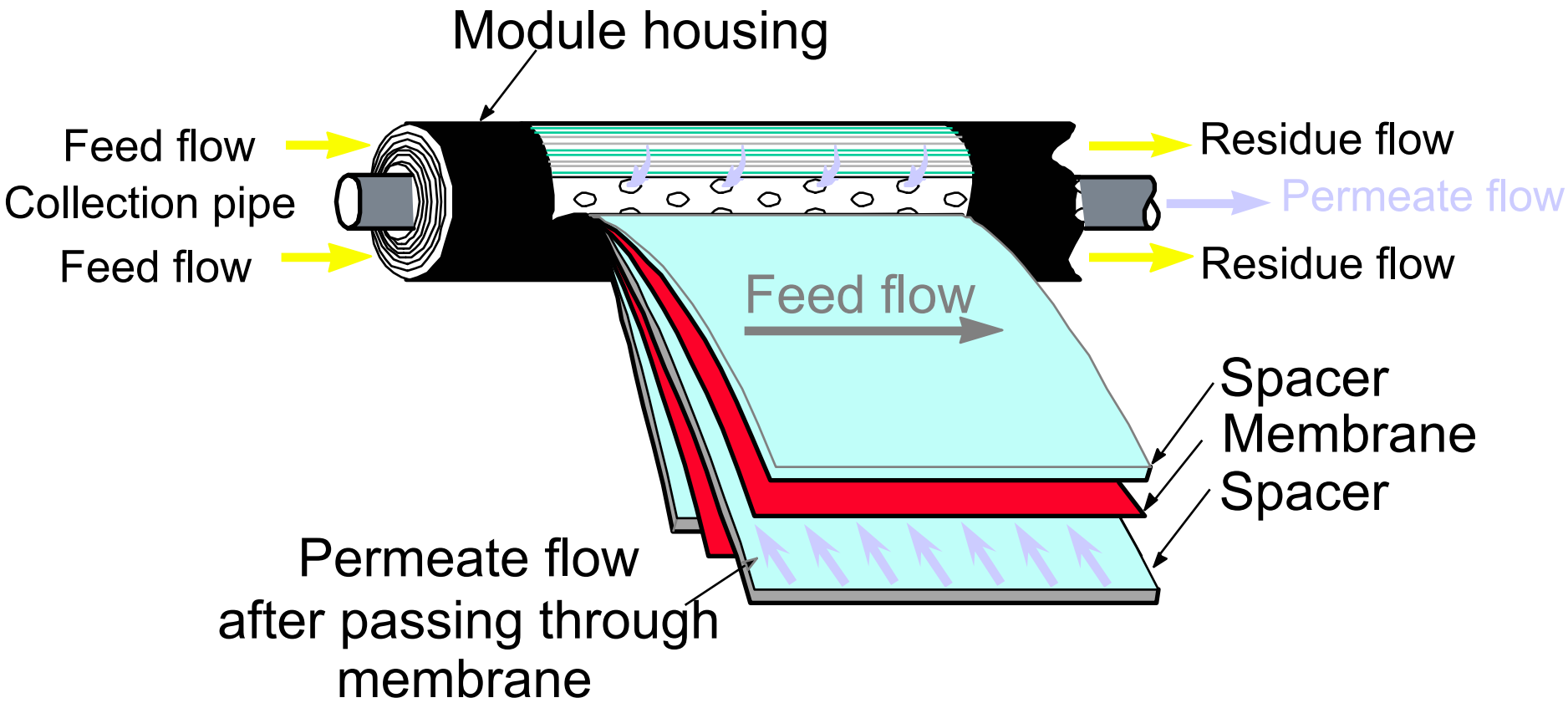
Permeation behavior of glassy polymers (diffusion dominates):

$$He > H_2 > CO_2 > O_2 > CO > N_2 > CH_4 > C_2H_6 > C_3H_8$$

Permeation behavior of glassy polymers (sorption dominates):

$$C_3H_8 > C_2H_6 > CO_2 > CH_4 > H_2 > O_2 > He > CO > N_2$$

MTR's Spiral-Wound Module



MTR GAS SEPARATION HISTORY

MTR has achieved a number of world wide "firsts" in commercializing novel and innovative gas separation applications:

1988: **First CFC and HCFC Recovery System,** 20 membrane systems installed

1992: **First VCM Recovery System in PVC Plant,** 14 membrane systems installed

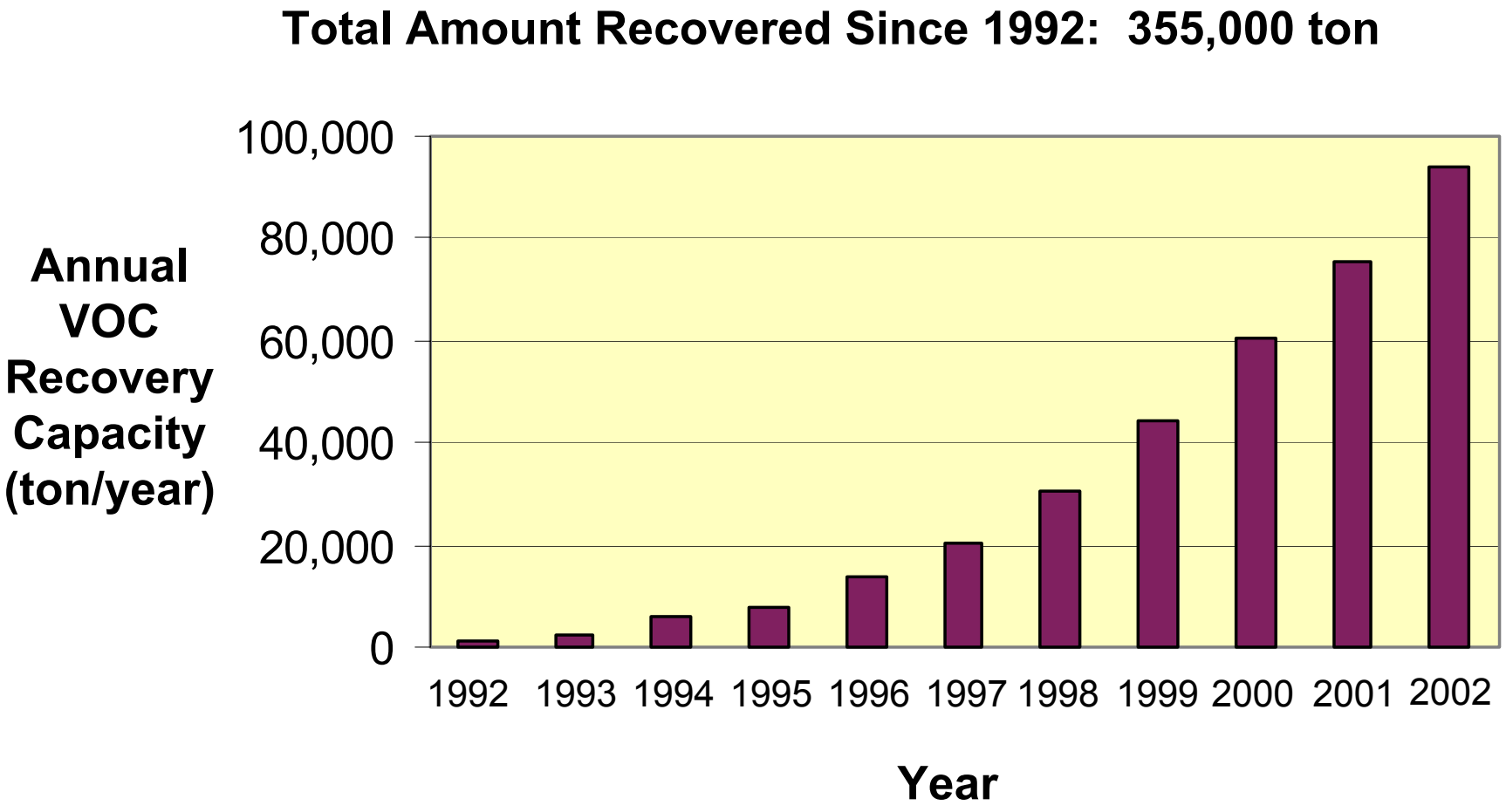
1996: **First Monomer Recovery System in PP/PE Plant,** 25 membrane systems installed, **Kirkpatrick Award**

1999: **First Ethylene Recovery System in Oxidation Reactor Process,** 3 systems installed

2001: **First Fuel Gas Conditioning System Installed** 3 systems installed

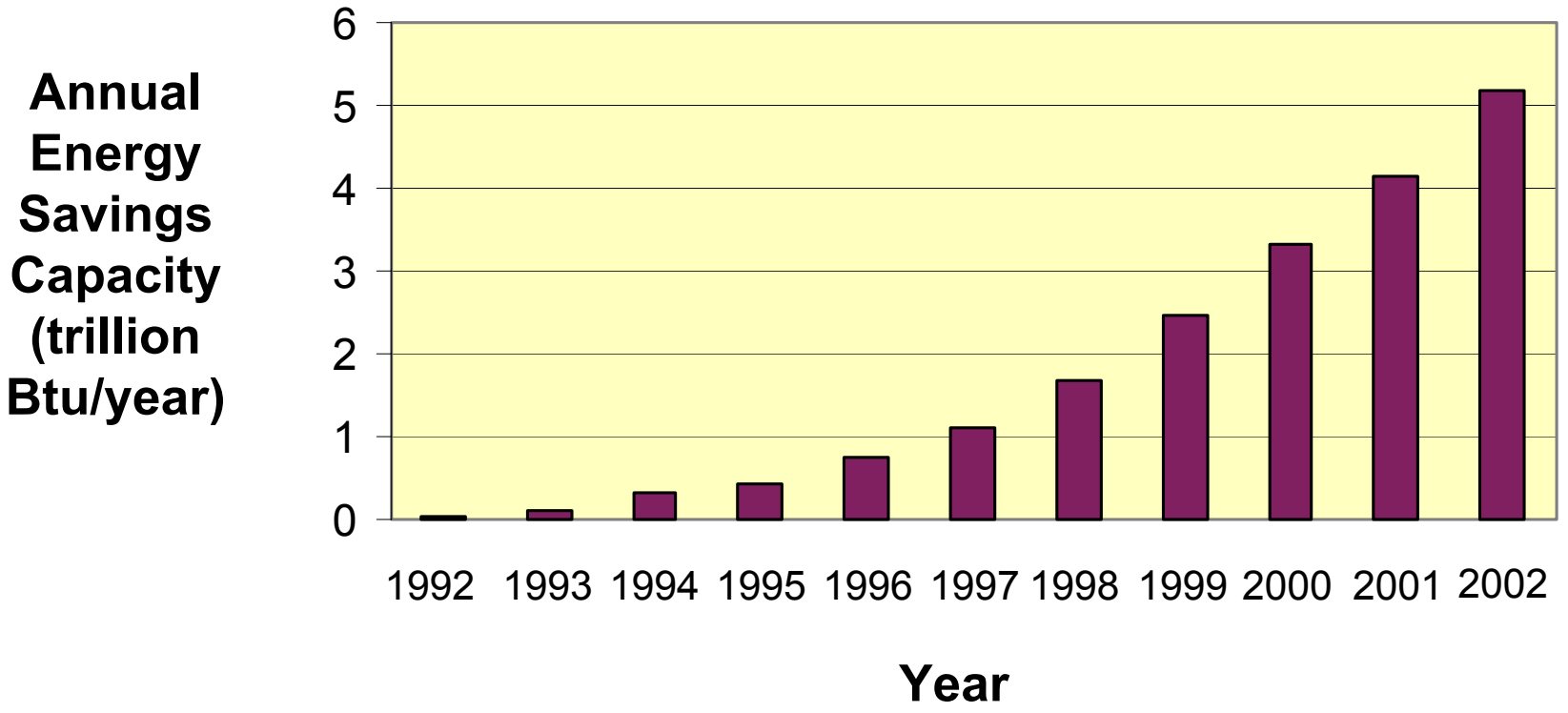
2002: **First Natural Gas Nitrogen Removal System Installed**

VOC Recovery Capacity of VaporSep Systems Installed in Chemical Processing Industry



Energy Savings Capacity of VaporSep Systems Installed in Chemical Processing Industry

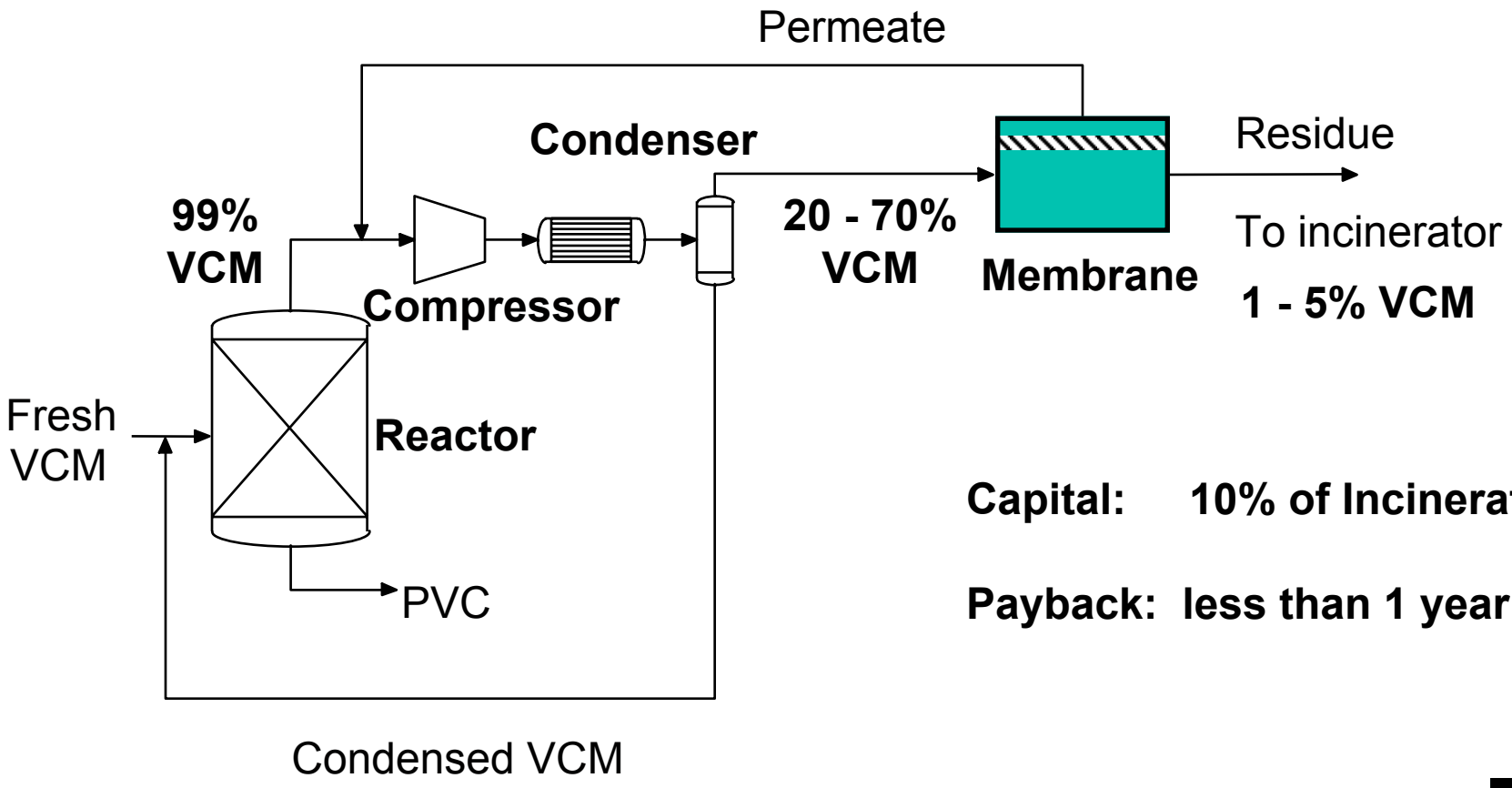
Total Energy Saved Since 1992: 19 trillion Btu



VaporSep Application Example: Recovery of VCM from PVC Manufacturing

- Problem: Loss of VCM through PVC reactor purge gas
  - Lost material = 0.5 to 5 million lb per year
  - Emissions restrictions
- Treatment alternatives:
  - Incineration + HCl scrubber
  - MTR VaporSep® system

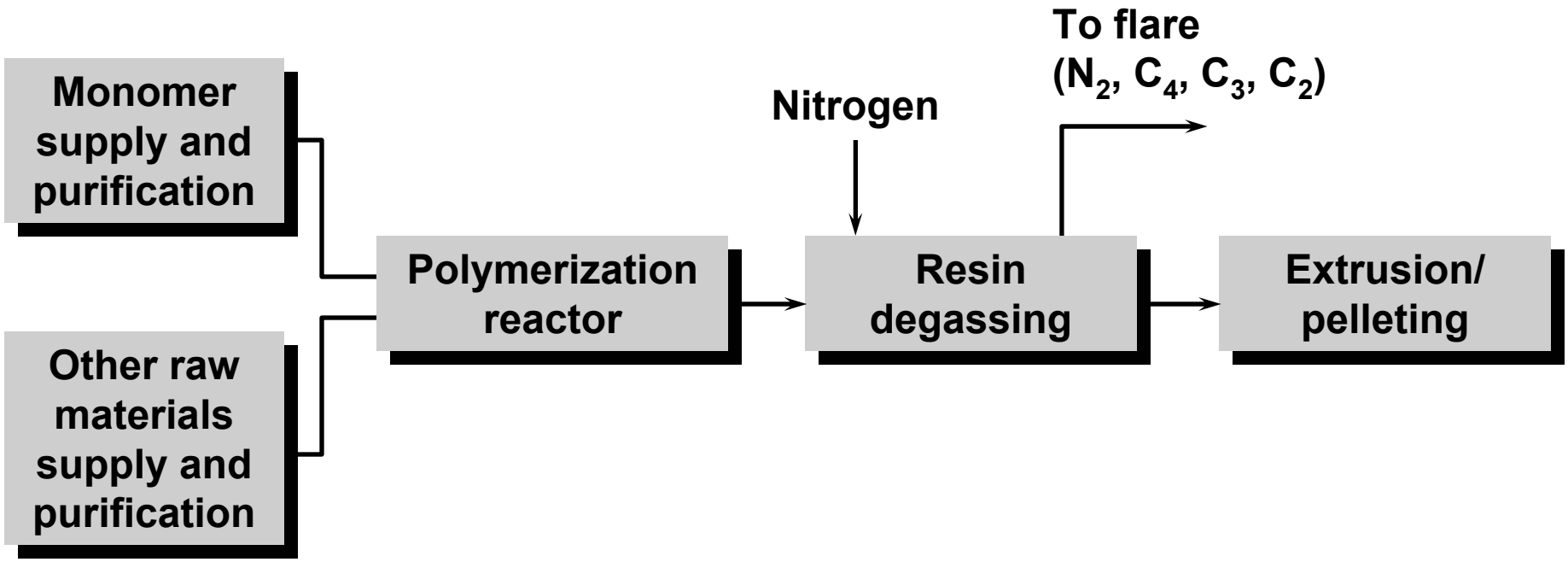
Vinyl Chloride Recovery in PVC Plant



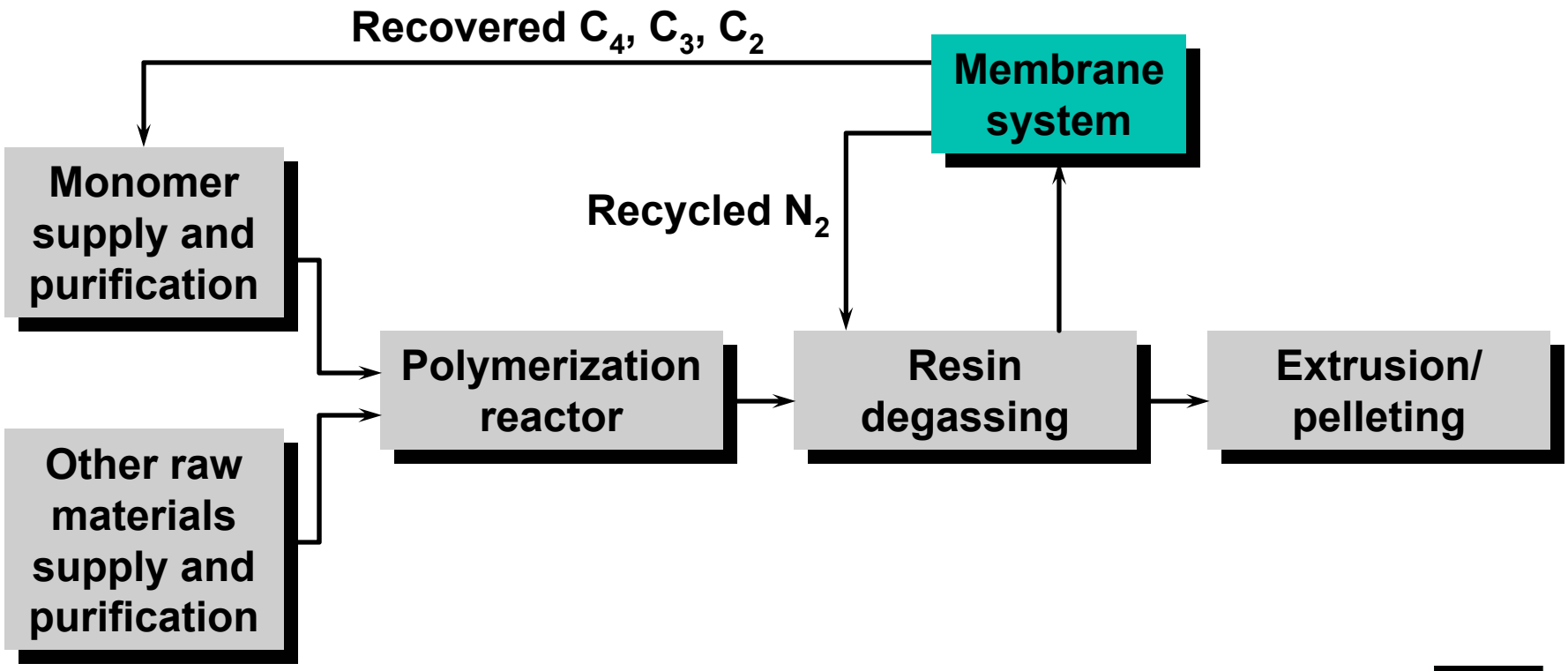
Capital: 10% of Incineration

Payback: less than 1 year

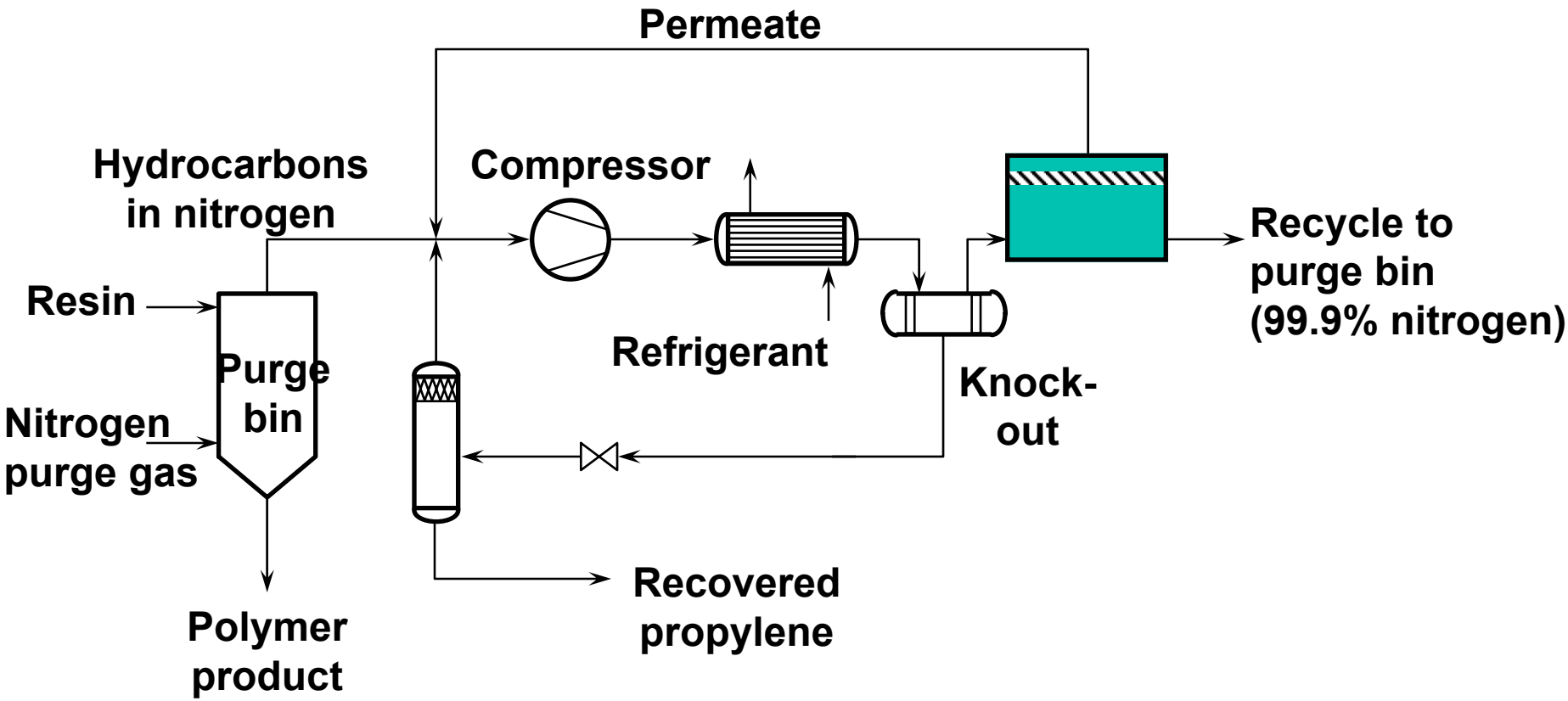
Polyolefin Production Process



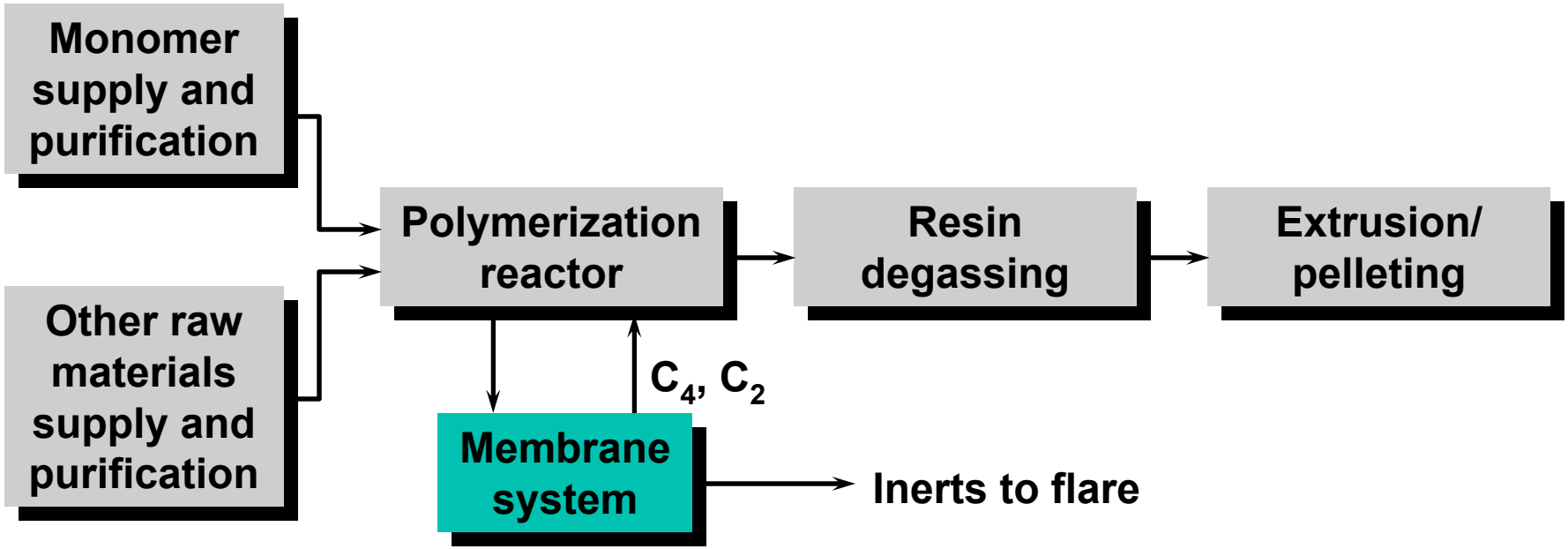
Membrane Recovery of Hydrocarbons in Polyolefin Manufacture: Purge Bin



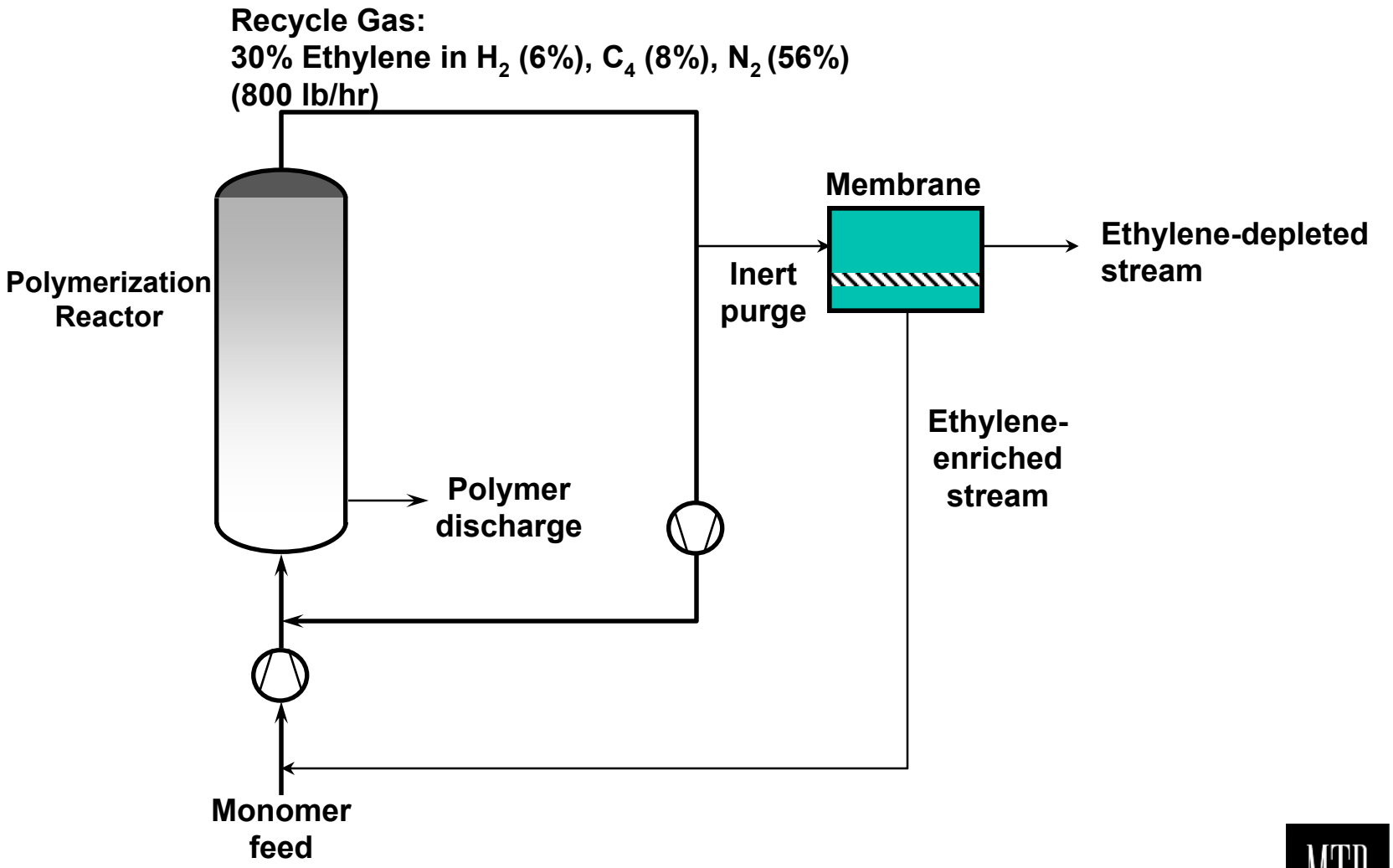
Propylene Recovery System



Membrane Recovery of Hydrocarbons in Polyolefin Manufacture: Reactor Purge



Reactor Purge Recovery



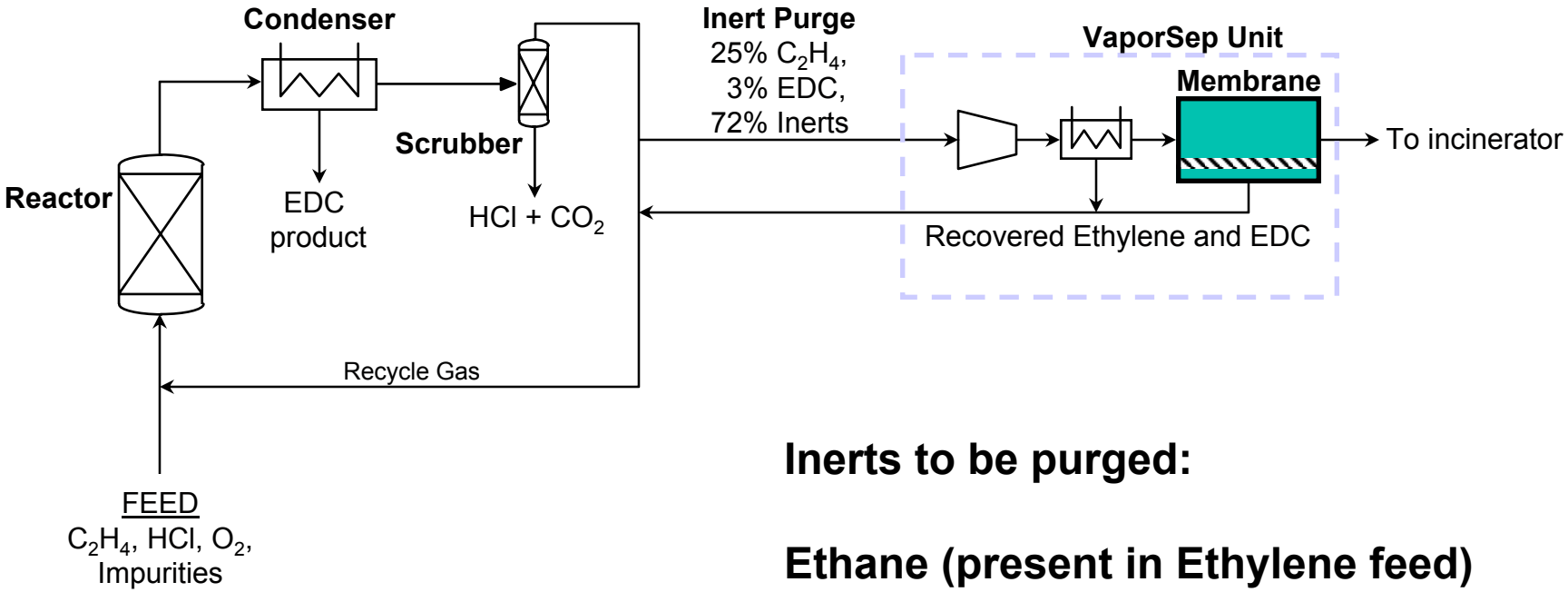
Reactor Purge Recovery

Component	**Recovery** (lb/hr)	**Credit** ($/lb)	**Annual Value** ($1000)
Ethylene	290	0.20	493
Butene	284	0.20	483
		Total:	**$ 976**

VaporSep system cost: $ 300,000

Power requirement: none

Ethylene Recovery in EDC Production



Inerts to be purged:

Ethane (present in Ethylene feed)
Argon (present in Oxygen feed)

Ethylene Recovery in EDC Production: Recovery Economics

Component	**Current Losses** (lb/hr)	**Losses with VaporSep** (lb/hr)	**Annual Value of recovered Material** ($/yr)
Ethylene	141	13	218,000
EDC	74	1	93,000
		Total:	**$ 311,000**

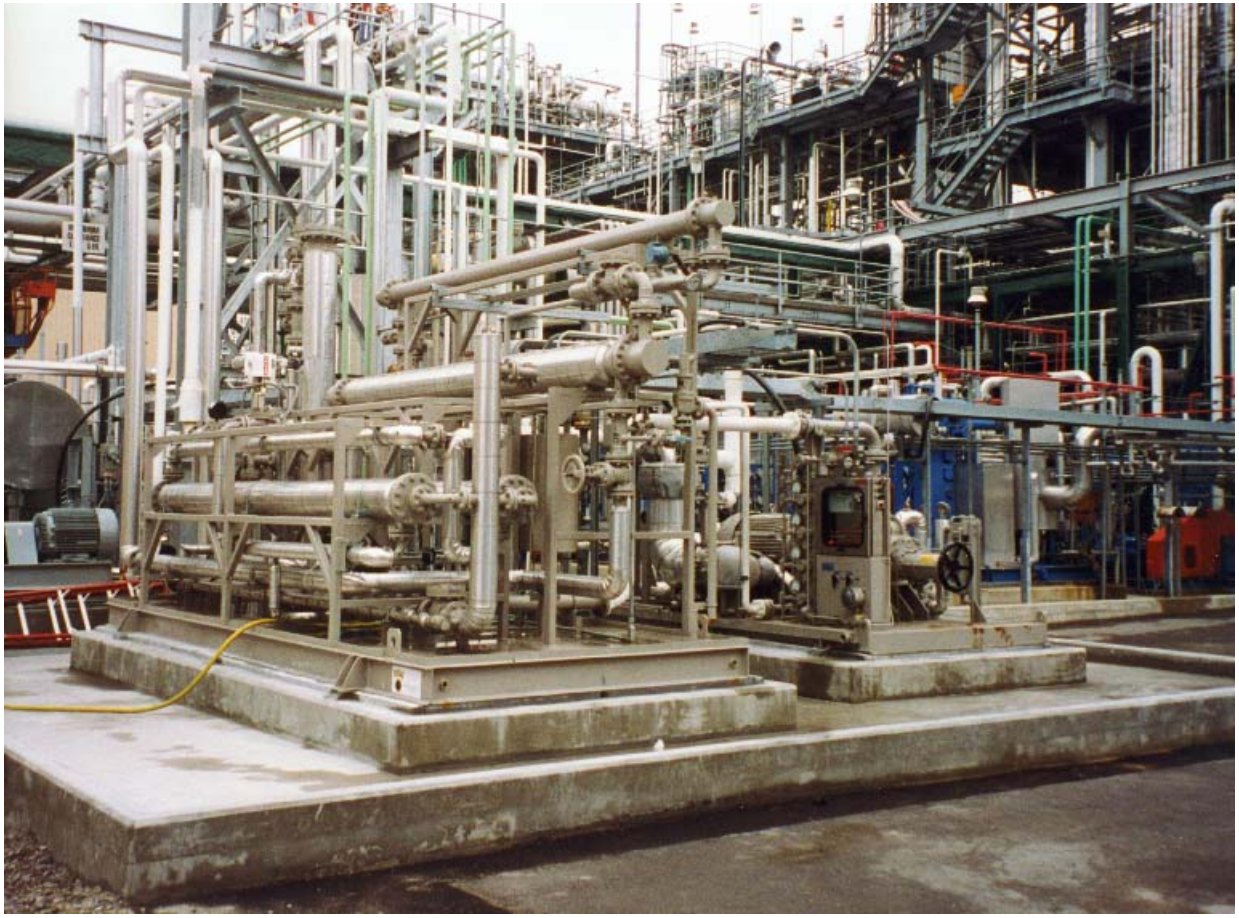
VaporSep system cost: $ 400,000

Power requirement: 50 HP

LIQUID PHASE SEPARATIONS

- **Pervaporation**
  - **Aroma and FRlavor recovery**
  - **Solvent Recovery / Waste Reduction**
  - **Ethanol Production through Fermentation**
- **Aqueous Nanofiltration**
  - **Oil / Water Separation (Bilge and Ballast Water)**
- **Organic Nanofiltration**
  - **Separation and Purification of vegetable Oils and Proteins from Extraction Solvents**
  - **Heterogeneous Catalysis**

Polyethylene Purge Bin Application



Chemopetrol Propylene Recovery System

Fabrication

Installed

Kemya Propylene Recovery System